

IODP Expedition 356: Indonesian Throughflow

Week 6 Report (6–12 September 2015)

Week 6 of Expedition 356 (Indonesian Throughflow) consisted of completing operations at Site U1462 (including another successful downhole logging deployment in Hole U1462C) and the start of operations at Site U1463 (proposed site NWS-2A). The science party was able to finalize all outstanding reports from Site U1461, particularly downhole logging and stratigraphic correlation, and begin finalizing their findings from Site U1462.

Operations

Week 6 began with improving poor borehole conditions in Hole U1462C so that coring could resume. After working the tight hole from 230.2 mbsf up to 178.3 mbsf, the overpull, torque, and pressure finally returned to normal levels. Two 30-barrel sweeps of high viscosity mud were pumped during stuck pipe operations to clear the hole of fallen debris.

The bit was lowered back to the bottom of the hole (242.0 mbsf), where there were no signs of fill. RCB coring resumed with half-length (4.8 m) advances and Cores U1462C-45R to 64R were recovered to 338.5 mbsf. We then switched to full (9.7 m) advances to recover Cores U1462C-65R and 66R to 357.9 mbsf, but a drop in core recovery led us to return to half-length advances after this. We then recovered Cores U1462C-67R to 132R to 678.9 mbsf. A single 6 m core (U1462C-133R) was then taken to adjust the correlation with Hole U1462A. Cores U1462C-134R to 143R (to 781.9 mbsf) were recovered with full advances. At 781.9 mbsf, we again changed back to half-length advances to try to optimize recovery. Apart from a single 3.5 m advance (Core U1462C-156R) to adjust the correlation with Hole U1462A, coring continued with half-length advances to the final depth of 950.0 mbsf (Core U1462C-178R) at 1030 h on 10 September. Core recovery was very low for the deepest 100 m (~10%). In Hole U1462C, we cored 917.0 m and recovered 398.29 m of material (43%).

After reaching the final depth, high viscosity mud was pumped through to clean the annulus of cuttings. We then attempted to release the bit to allow wireline logging of this hole, but the driller noticed bottom contact on the weight indicator. Several attempts were made to shift the mechanical sleeve to release the bit. The drill string was worked back up to 929.0 mbsf and the bit finally released. The driller then lost string rotation with high torque and high pressure. After working the pipe with rotation, overpull, and circulation, the pipe came free. The drill string was pulled to 725.1 mbsf where heavy mud was used several times in an effort to stop the reverse flow before the mechanical bit release sleeve was shifted back. The drill string was then pulled to 307.1 mbsf, the circulating head was installed, and the hole was displaced with heavy mud in preparation for logging. The drill string was then pulled up to logging depth (89.4 mbsf) and preparations for logging began at 2130 h on 10 September. The triple combination tool string was the first deployment. The tool string contained the following tools: magnetic susceptibility

sonde (MSS), Hostile Environment Natural Gamma Ray Sonde (HNGS), Hostile Environment Litho-Density Tool (HLDT), Enhanced Digital Telemetry Cartridge (EDTC), and logging equipment head-q tension (LEH-QT). The tool string was deployed at 2330 h on 10 September. After the tool string exited the drill pipe, the active heave compensator was turned on. A downlog was performed from just above seafloor to 896 mbsf. The hole was then logged up with the triple combo to ~90 mbsf. The tools arrived back on the rig floor at 0300 h on 11 September. The Versatile Seismic Imager (VSI) tool string was the next scheduled deployment to take advantage of daylight which is required for protected species watch when using seismic sources. A caliper extension was added to the tool because of the large borehole size (17 inch in the upper section). The tool string was deployed to the seafloor at 0445 h after which we were on standby until daylight. The protected species observations began at sunrise and at 0645 h, the VSI tool string was lowered to the bottom of the hole. At 0740 h, the VSI experiment began. Starting from 773 mbsf, a series of ~25 m stations were tested at ~10 min per station. The last station tested was at 107 mbsf. After concluding the first successful VSI experiment during this expedition, the tools were pulled from the hole and were back on the rig floor at 1355 h on 11 September. After rigging down the VSI tool string, the FMS-sonic tool string was assembled with the following tools: Formation MicroScanner (FMS), Dipole Sonic Imager (DSI), Hostile Environment Natural Gamma Ray Sonde (HNGS), Enhanced Digital Telemetry Cartridge (EDTC), and the logging equipment head-q tension (LEH-QT). At 1550 h, the tool string was lowered without difficulty through the drill pipe to just above the seafloor. The logging tools were turned on and the hole was logged down to 770 mbsf. The hole was logged up to just below the end of pipe (89.4 mbsf). A second pass was made over the total length of open hole. The tool string arrived back on the rig floor at 2145 h on 11 September.

The drill string was pulled out of the hole and cleared the seafloor at 2235 h. The upper guide horn was pulled and the moonpool doors were opened to deploy the subsea camera system. A 50 m box survey of the seafloor was performed around Hole U1462C. After completing the survey, the subsea camera system was recovered, the remainder of the drill string was pulled back to surface, and the vessel was secured for transit. The seafloor positioning beacon was recovered at 0214 h on 12 September, ending Site U1462. The total time spent on Hole U1462C was 182.75 h (7.6 d). The total time spent on Site U1462 was 323.0 h or 13.5 d.

At 0400 h on 12 September, the vessel started the transit to Site U1463. After a 131 nmi transit (11.5 h), the ship arrived at Site U1463 at 1530 h on 12 September. A seafloor positioning beacon was deployed, the vessel was offset from the beacon, and we began preparations for coring. The APC/XCB system was assembled. Given the previous difficulty with the mudline core on Sites U1459 and U1462 (broken and bent core barrels, respectively), we decided to begin coring operations with the XCB coring system. We tagged the seafloor with the bit and calculated the water depth to be 145.8 mbsl. Hole U1463A was started at 1925 h. The first XCB core returned empty (Core U1463A-1X) and the second core (Core U1463A-2X) recovered 8.59 m of soft mud, so we decided to abandon Hole U1463A in order to begin a new hole (Hole U1463B) with the APC system. Hole U1463A penetrated to a final depth of 19.4 mbsf (89%

recovery). Hole U1463A ended at 2030 h on 12 September. The total time spent on Hole U1463A was 9.75 h. Hole U1463B began shortly after with recovery of a mudline core (7.88 m). The water depth was calculated to be 145.3 mbsf. Coring in Hole U1463B with the APC system continued through the end of the week to 74.4 mbsf (Cores U1463B-2H to 8H).

Science Results

Lithostratigraphy

The lithostratigraphy of Site U1462 is divided into four units. Unit I (~300.9 m thick in Hole U1462A; ~47.8 m in Hole U1462B; ~256.7 m in Hole U1462C) is characterized by partially to fully lithified, light grayish green to dark greenish gray, non-skeletal packstones with lesser amounts of skeletal pack- to grainstone. The grainstone consists mainly of medium sand-sized to coarse sand-sized grains with minor amounts of gravel and fine sand. The packstones contain macrofossils, peloids, and ooid intervals. Common macrofossils include bivalves, gastropods, barnacles, solitary corals, echinoderms, scaphopods, bryozoans, brachiopods, and serpulids. Small and larger benthic foraminifera are common, whereas planktic foraminifera are scarce. Some sedimentary structures, such as planar laminations, slight to moderate bioturbation, and sharp to wavy, gradational, and bioturbated contacts are visible in the few cores with greater recovery.

The transition from Unit I to Unit II is characterized by the disappearance of large peloids, a distinct increase in planktic foraminifers and siliciclastic components, and a transition from neritic to hemipelagic facies. Unit II (~476.40 m thick in Hole U1462A; ~521.18 m thick in Hole U1462C) is composed largely of lithified olive gray packstones with some wackestone intervals. Grain size is gradational, from very fine sand-size grains to coarse sand-size grains towards the base of Unit II. Diverse and abundant macrofossils in the upper part of Unit II include bivalves, gastropods, scaphopods, bryozoa, and echinoderms, but bioclasts (mainly bivalve fragments) become much less common with depth. In contrast, small benthic foraminifers are fairly common throughout Unit II. Bioturbation is variable throughout the unit, and there is evidence for gravitational flows and other small-scale mass-transport deposits (e.g., laminations, grading, contact surfaces) towards the base of Unit II.

Unit III (~65.73 m thick in Hole U1462A; ~66.88 m thick in Hole U1462C) is distinguished from Unit II by higher quartz content. In Hole U1462A, Unit III consists of lithified, gray to olive gray packstone with fine to medium sand-sized quartz grains and various macrofossils, including bivalves, gastropods, bryozoans, echinoderms, and small benthic foraminifers. In Hole U1462C, the transition between Unit II and Unit III is characterized by a change in the lithology from packstone to grainstone and a marked contact (a pyrite-rich cemented interval). Below the grainstone interval, Unit III is composed mainly of packstone with primarily coarse to medium sand-sized grains; disseminated pyrite is also common. At the base of the unit, the lithology

transitions to dark greenish gray, coarse-grained, poorly sorted sandstone, containing common large benthic foraminifers. Bioturbation is more severe in Hole U1462C than Hole U1462A, while sedimentary features (e.g., parallel laminations, grading, bioturbated contacts) are similar throughout the unit in both Holes.

Unit IV (~6.57 m thick in Hole U1462A; ~101.33 m thick in Hole U1462C) is composed primarily of dolostone and quartz-rich sandstone and is characterized by common anhydrite nodules, intervals of anhydrite rock, and associated chicken wire structures. The start of Unit IV is defined by the first appearance of macroscopic anhydrite nodules and an increase in dolomite (seen in thin sections). Unit IV varies in color from light brown to gray to white (anhydrite nodules and anhydrite rock) with generally coarse to medium sand-sized grains and brief intervals of fine sand. Bioturbation is slight to moderate but sporadic throughout the unit. Burrows are often filled with dolomite. Macrofossil fragments occur in low numbers throughout the unit, and include solitary corals, bivalves, echinoderms, small benthic foraminifers, and fossil molds (e.g., gastropods and bivalves). Parallel laminations are more frequent in the upper part of the unit, while karstic cavities and intermittent moldic porosity appear in the lower part. Contact surfaces are uncommon, but if present, typically form sharp, subhorizontal surfaces. Pyrite grains are intermittently common and sometimes rim intraclasts, quartz, and anhydrite grains.

Biostratigraphy and Micropaleontology

During week 6, the biostratigraphy team finished processing core catcher samples from Hole U1462C at 20 m intervals and completed analyses at Site U1462. A total of 155 smear slides were examined for calcareous nannofossil marker species and common taxa. Analyses were done at 10 m resolution in selected intervals to better constrain biostratigraphic datums between Holes U1462A, U1462B, and U1462C. Calcareous nannofossils recovered in Holes U1462A and U1462C represent a complete stratigraphic succession from the late Miocene to late Pleistocene (Zones NN11–NN21). The bottom of Hole U1462B (47.8 mbsf) was dated to early Pleistocene age based on the presence of *P. lacunosa* (>0.44 Ma; Zone NN19). Calcareous nannofossils are (very) rare with poor to moderate preservation in sediments recovered within the upper 325 m (late Pleistocene), and are few to abundant with moderate to good preservation between 325–844 mbsf (late Miocene–earliest late Pleistocene). The Pliocene/Pleistocene boundary is placed between 527.5–539.97 mbsf, based on the (rare) presence of *Discoaster surculus* (Top at 2.49 Ma). Reworked Oligocene and middle Miocene taxa (e.g., *Reticulofenestra bisecta* and *Cyclicargolithus floridanus*) were rare to common between 580–830 mbsf in both Holes U1462A and U1462C (Samples U1462A-61X-CC to 95X-CC and U1462C-113R-CC to 152R-CC). The Miocene/Pliocene boundary falls within Biozone NN12, which was difficult to constrain due to the lack of *Ceratolithus* marker species, but is tentatively placed between 777.56 mbsf (>4.12 Ma) and 809.15 mbsf (>5.59 Ma). Barren intervals are found within the upper 30 m in Hole U1462B, the bottom of Hole U1462A (844.8–849.67 mbsf, Samples U1462A-99X-CC and 100X-CC), and 844.69 mbsf to the bottom of Hole U1462C (946.09 mbsf).

Forty-five samples were examined from Hole U1462C this week for planktonic foraminifers. Preservation ranged from (very) poor to moderate with frequent barren intervals in the Pleistocene, although other bioclasts were present. The poor preservation in Hole U1462C (down to ~350 mbsf) was accompanied by less than four identifiable species per sample. From ~350–845 mbsf (Early Pleistocene and Pliocene) preservation was slightly better (poor to moderate) and accordingly, abundance of planktonic foraminifers increased. Poor preservation and barren samples were encountered again below ~845 mbsf (Sample U1462C-157R-CC). Despite the improvement in preservation and abundance in the Early Pleistocene/Pliocene section, beginning ~368 mbsf, it is still relatively poor in comparison to Sites U1460 and U1461. The overall diversity varied from five to 14 species per sample with the highest diversity in samples deeper than 370 mbsf (Sample U1462C-69R-CC), which contained up to 80% planktonic taxa in comparison with benthic taxa. As the general preservation is poor, many of the biozone markers found at previous sites, such as *G. limbata*, *P. primalis*, and *S. seminulina*, are not present. However, a comparison of the early Pleistocene and Pliocene sections (~4–2 Ma) of Site U1462 with Site U1461 reveals a similar sedimentary sequence, which is expanded at Site U1462 (250–300 m). Below ~820 mbsf, planktonic foraminiferal abundance rapidly decreases and samples are either barren, unidentifiable, or heavily dolomitized.

At Site U1462, 48 samples were examined from Hole U1462C for benthic foraminifers. Preservation is generally poor; however, there are frequent horizons (e.g., Samples U1462C-109R-CC to 113R-CC; 565.65–584.75 mbsf) where it increases to moderate, often accompanying a foraminiferal assemblage change that suggests transported material. Poor preservation is largely a result of abrasion and encrustation by calcite, iron, micrite, and dolomitization. The number of species per sample ranges from 0 to 25 with an average of 14. The samples remain largely dominated by *Cibicides* spp. and *Cibicidoides* spp. and dominant species within isolated intervals include *Bolivina* spp., *Brizalina semilineata*, *Lenticulina* spp., *Uvigerina* spp., *Uvigerina peregrine*, and lenses of other large foraminiferal species including *Neoeponides margaritifer* and *Pseudorotalia* spp.

Geochemistry

Headspace gas concentrations in Hole U1462C were low compared with Hole U1462A. No samples for interstitial water were taken from Hole U1462C due to extremely low water content in the sediment below 855 mbsf because of the presence of quartz-rich siliciclastics and evaporites. Therefore, geochemical analyses on the squeeze cake and interstitial water samples from Hole U1462A, including total organic and inorganic carbon content, total nitrogen, and major and minor element content, were finished. A drastic drop in weight percent of calcium carbonate (from >80% to 3.3%) is noted at between 845 and 850 mbsf. This interval corresponds to the boundary between lithostratigraphic Units III and IV. The carbonate content then increases again to ~50% at the bottom of Hole U1462C (~950 mbsf).

Paleomagnetism

Paleomagnetic investigations focused on natural remanent magnetization and alternating field demagnetization (AFD) measurements from Hole U1462C. More than 200 archive-half core sections were measured on the superconducting rock magnetometer before and after AFD at 10 and 20 mT. Intensity values ranged from 10^{-5} to 10^{-3} A/m. A clear reversed polarity interval occurs between 537.6–586.0 mbsf. Incorporating biostratigraphic datums of 3.70 Ma (584.7 mbsf) and 3.54 Ma (565.6 mbsf), this reversal could be correlated with C2Ar (3.596–4.187 Ma) at the upper part of the Gilbert chron. Rock magnetism studies were complemented by XRD analyses of discrete samples from Hole U1462A. Iron sulfide minerals, such as griegite and pyrrhotite, were confirmed in analyzed samples.

Physical Properties

Physical properties measurements were carried out using the Whole-Round Multisensor Logger (WRMSL), natural gamma ray (NGR) sensor, and discrete sampling from cores of Hole U1462C. Between 300–840 mbsf, measurements of magnetic susceptibility and NGR revealed 20–30 m scale variations in these properties. A relatively high-resolution sampling scheme for moisture and density (MAD) and smear slides in four consecutive 4.5 m cores validated these cycles and confirmed that the cyclicity is driven by variations in clay content. *P*-wave velocities were scattered in the top 300 m and below 840 mbsf, the latter of which consists of fully lithified material. The *P*-wave velocities of many MAD samples were measured, showing that these rocks tended to have a high degree of anisotropy. Additionally, these data allowed us to determine a power-law relationship between bulk density and *P*-wave velocity for this site. Overall, the *P*-wave velocities measured in Hole U1462C were similar to those in Hole U1462A. Porosities in the packstone of lithostratigraphic Unit II decrease from about 43% (300 mbsf) to 27% (840 mbsf), while the rocks above this unit show variable porosities and those deeper show variable but lower porosities.

Downhole Logging

We finalized the Site U1461 report and began preparing the Site U1462 report. The processed logs from Hole U1462A were received halfway through the week, which allowed for the analysis of these results to begin. In addition, we also collected logs in Hole U1462C this week. In Hole U1462C, three successful tool string deployments (triple combination, Formation MicroScanner [FMS]-sonic and Versatile Seismic Imager [VSI]) were accomplished. Contrary to the logging operations at Hole U1462A, the triple combo tool string was deployed with sources; therefore, bulk density and porosity data were collected from Hole U1462C to 896 mbsf. Subsequently, a successful run with the VSI was carried out between 773 and 107 mbsf with stations generally every 25 m (10 min/station). This strategy yielded two to five successful measurements per station, so that individual measurements could be stacked to reduce the noise level. Finally, we carried out two full passes with the FMS-sonic between 770 and 75 mbsf. The sonic velocities

measured with the FMS-sonic tool string are in agreement with the Vertical Seismic Profile that was obtained with the VSI.

Stratigraphic Correlation

The Site U1461 correlation files (affine table, splice) and report were finalized. The splice covers the upper 285 m, with less confidence in the correlation in some intervals between 240 and 285 mbsf as a result of low variations in NGR data and the use of the HLAPC (more recovery gaps). Correlating the core data to the wireline logs from Hole U1461D provided exceedingly useful information as to the completeness of the recovered section in the deeper part of Holes U1461B and U1461D, and assisted in filling in recovery gaps. While a hanging splice could not be generated, correlation was possible and will provide guidance for subsequent sampling.

For Site U1462, the processed wireline data from Hole U1462A was received, so it was possible to correlate it to the core-based NGR data from Holes U1462A and U1462C. This was less successful than at Site U1461. Hole U1462C coring was completed and the hole was logged. Recovery of a continuous sedimentary section was not possible in this hole, so a splice will not be generated; however, similar to the deeper sections at Site U1461, a core-log integration will likely enable us to provide guidance for sampling. The Site U1462 report was begun, but finalization awaits integration of the processed wireline data from Hole U1462C and finalized lithostratigraphic units for all holes.

Education and Outreach

The education and outreach officers hosted six school broadcasts this week: University of North Carolina (freshmen; Wilmington, NC, USA), Cornell College (freshmen/sophomores; Mt. Vernon, IA, USA), Kerrimur Primary School (3rd grade, Box Hill, VIC, Australia), Bendigo Discovery Centre (teachers; Bendigo, VIC, Australia), Alaska SeaLife Center (middle school ocean sciences club members; Seward, AK, USA), and Animo High School (seniors honor marine biology; Inglewood, CA, USA). They also continue to engage with social media, post blogs, work on individual projects, and have scheduled a Reddit “Ask Me Anything” for 19 September.

Technical Support and HSE Activities

Technical staff primary activities included archiving of cores from Hole U1462C and initial archiving of the first cores from Hole U1463A and U1463B, supporting core flow through the laboratories, and laboratory maintenance. Technical staff provided protected species watch and seismic source for successful Vertical Seismic Profile.

Laboratories

- Physical Properties
 - PWAVE_C issue diagnosed and resolved by the application developers.
 - Section Half Multisensor Logger (SHMSL) MSPOINT experiencing data shift; being diagnosed.
- Chemistry
 - Source rock analyzer (SRA) issues continue and are being diagnosed.

HSE Activities

- Safety showers and eyewash stations were tested.
- A fire and boat drill was conducted on 13 September.